



U.S. DEPARTMENT OF
ENERGY

Nuclear Energy

Getting from Where We Are to Where We Want to Be in Fuel Cycle Technologies

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Office of Fuel Cycle Technologies

FY 2012 Nuclear reactor Technologies Summit
Gaithersburg, MD
March 20, 2012





Outline

- Domestic Energy Background
- Where We Are Today in Fuel Cycle Technologies
- Where Do We Want to Be?
- Current Fuel Cycle R&D Portfolio
 - Near Term Needs
 - Long Term Needs
- Where Do We Want to Be?
- Concluding Remarks
- Workshop Announcements



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Domestic Energy Background

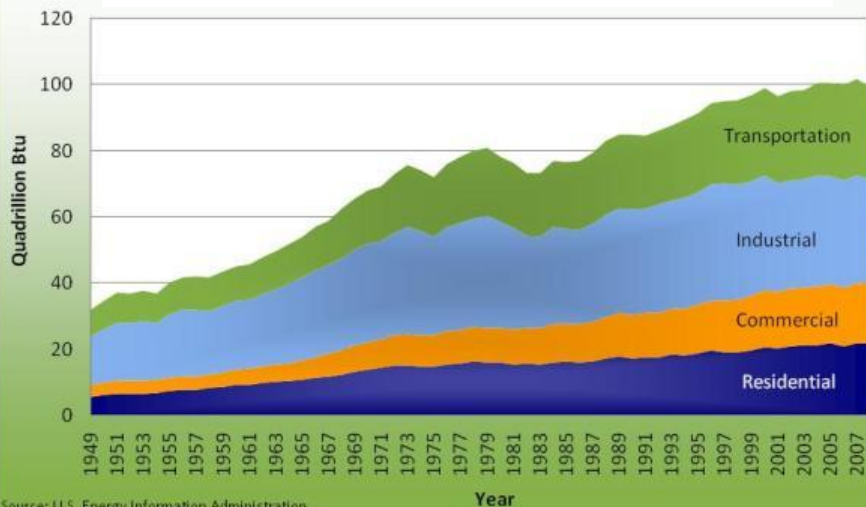


Situational Analysis in the United States

Nuclear Energy

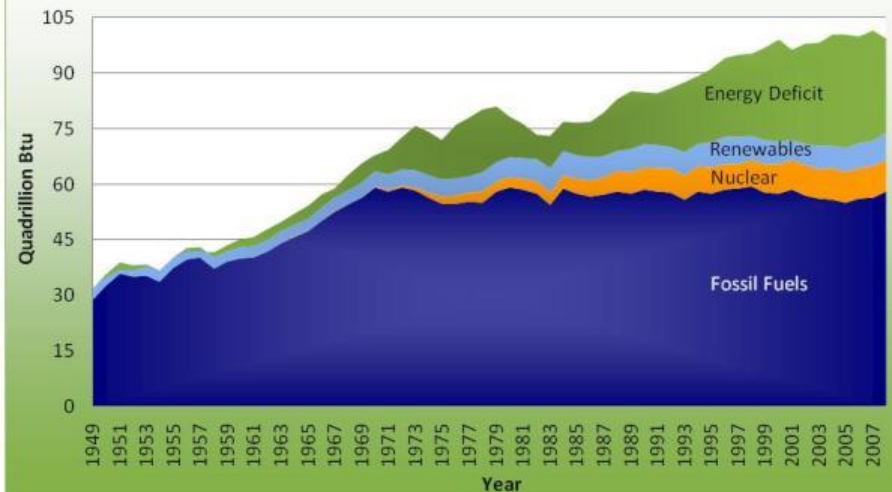
- **Energy is involved in securing our way of life in three major areas:**
 - Energy security
 - Economic security
 - Environmental security
- **Rising energy demands, our security, our prosperity, and our environment all require reducing dependence on fossil fuels that emit greenhouse gases**

Rising Energy Demands by Sector:1949-2008
Quadrillion Btu



Source: U.S. Energy Information Administration

U.S. Energy Use, Production & Deficits:1949-2008
Quadrillion Btu





Nuclear Energy in the United States

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■ Nuclear energy already provides approximately one-fifth of electricity used to power factories, homes, and schools

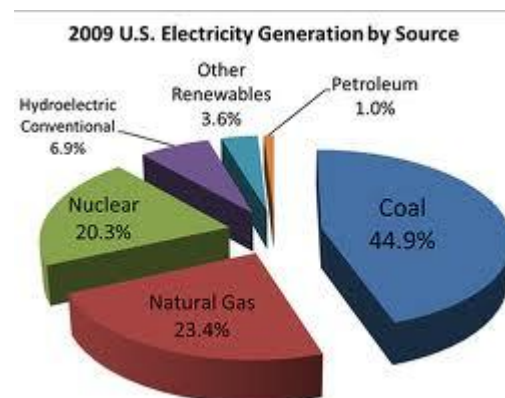
- 104 operating nuclear power plants, located at 65 sites in 31 states
- A combined license (COL) was recently issued for 2 new reactors in South Carolina

In some states nuclear energy provides a greater role compared to the national average

■ Sources of electricity in Illinois (October 1, 2009 to September 30, 2010 ComEd):

- 53% from Nuclear Power
- 36% from Coal Fired Power
- 7% from Natural Gas
- 3% from Wind, Biomass, or Hydro Power
- 1% Other

■ City of Chicago receives about 75% of its electricity from nuclear power





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Nuclear Energy Role in National Energy Portfolio

Nuclear Energy Must Play an Important Role in Any Future National Energy Portfolio

Proven over the last 40 years to be safe, reliable, and affordable

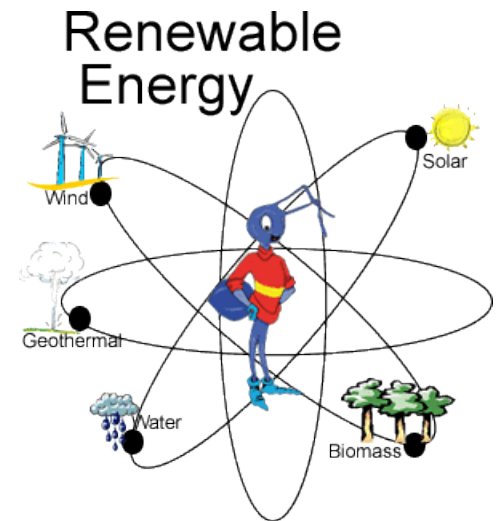
*Good for
Economic Security*

Technology and fuel can be domestically produced

*Good for Energy
Security*

Nearly free of greenhouse gas emissions

*Good for
Environmental
Security*





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President Obama's Commitment to Clean Energy

“This country needs an all-out, all-of-the-above strategy that develops every available source of American energy.”

*President Barack Obama
State of the Union Address
January 24, 2012*





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Where We Are Today in Fuel Cycle Technologies



Where We Are Today

Global demand for energy and concerns about climate change has accelerated deployment of reactor and fuel cycle facilities worldwide

There is a continuing build up of nuclear waste from commercial nuclear plants and stockpile of DOE wastes stored across the country.

After Fukushima – new awareness as a country of the need for a waste management strategy

- Interim storage
- Fuel cycle alternatives
- Disposal options

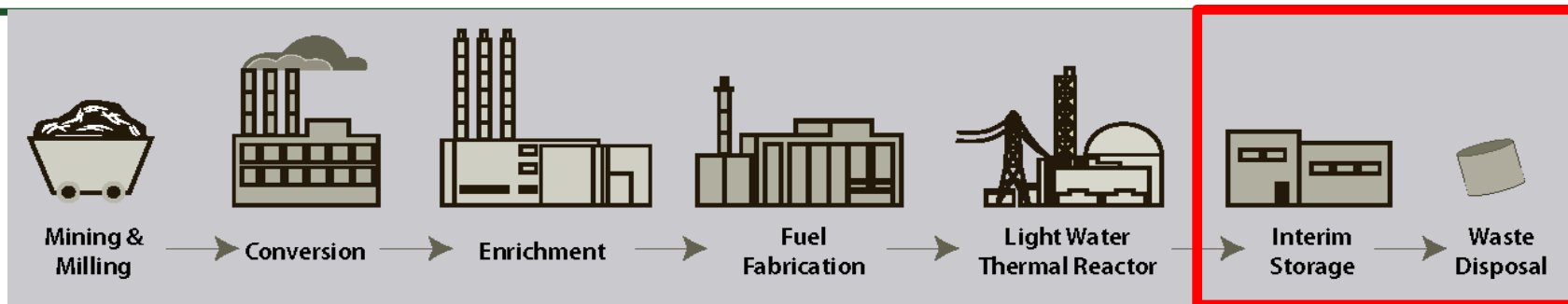


The BRC conducted a comprehensive evaluation of policies for managing the back end of the nuclear fuel cycle, including advanced fuel cycle technologies

The Fuel Cycle Technology Program seeks to develop innovative technologies that represent significant advantages in terms of economics, proliferation resistance, resource utilization and waste management



The U.S. Open Fuel Cycle is Still Incomplete – Missing Two Facilities



R&D considerations

- Are there ways to isolate the SNF or its constituents for the very long term?
- Are there proliferation issues associated either with long-term accumulation or treatment and recycle of SNF?

Is used fuel a waste or a resource?

Used fuel contains:

- Fissile isotopes that could be recovered and re-used in nuclear fuel
- Isotopes that are radioactive for long time periods that would cause environmental and health impacts if released.

U.S. path forward

- Used fuel can be stored safely for decades
- BRC provided recommendations that help guide management of used nuclear fuel and fuel cycle R&D
- BRC affirms the need for R&D on advanced fuel cycles that represent advantages over today's technologies.



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Where Do We Want to Be?



Two Main Needs

■ Near Term - Complete our open fuel cycle

- Address key missing facilities
 - Interim Storage
 - Waste Disposal
- Next generation domestic enrichment technologies

■ Long Term – Focus on sustainable fuel cycles

- Currently evaluating the benefits of moving from an open to a closed or partially closed fuel cycle

**The Office of Nuclear Energy Fuel Cycle Technologies
Program addresses both near term and long term needs**





Fuel Cycle Technologies Requires Multidisciplinary Research and Development Capabilities

Front End



Uranium Resources

- Conventional production 
- Innovative approaches 



Fuel Fabrication

- Safety enhanced LWR fuel
- Higher performance

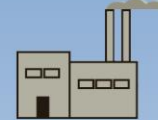


Reactors



Interim Storage

- Evaluating extended time frames
- Transportation after storage



Recycle

- Separations
- Recycled fuel
- Secondary waste treatment



Disposal

- Alternative geologies
- Alternative waste forms

Back End

Optimize Through Systems Analysis and Engineering



Near Term Needs



Long Term Needs



Uranium
Resources

- Conventional production ←
- Innovative approaches

Current Fuel Cycle R&D Portfolio:

Near Term Needs

Front End ←

Back End

Long Term Needs

Front End

Back End



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Small R&D Effort in Mining – jointly funded with State of Wyoming



***Exploratory
Drilling***

Photographs: Drill rig -
<http://www.cameco.com>,
Others - Office of Nuclear Energy,
U.S. Department of Energy



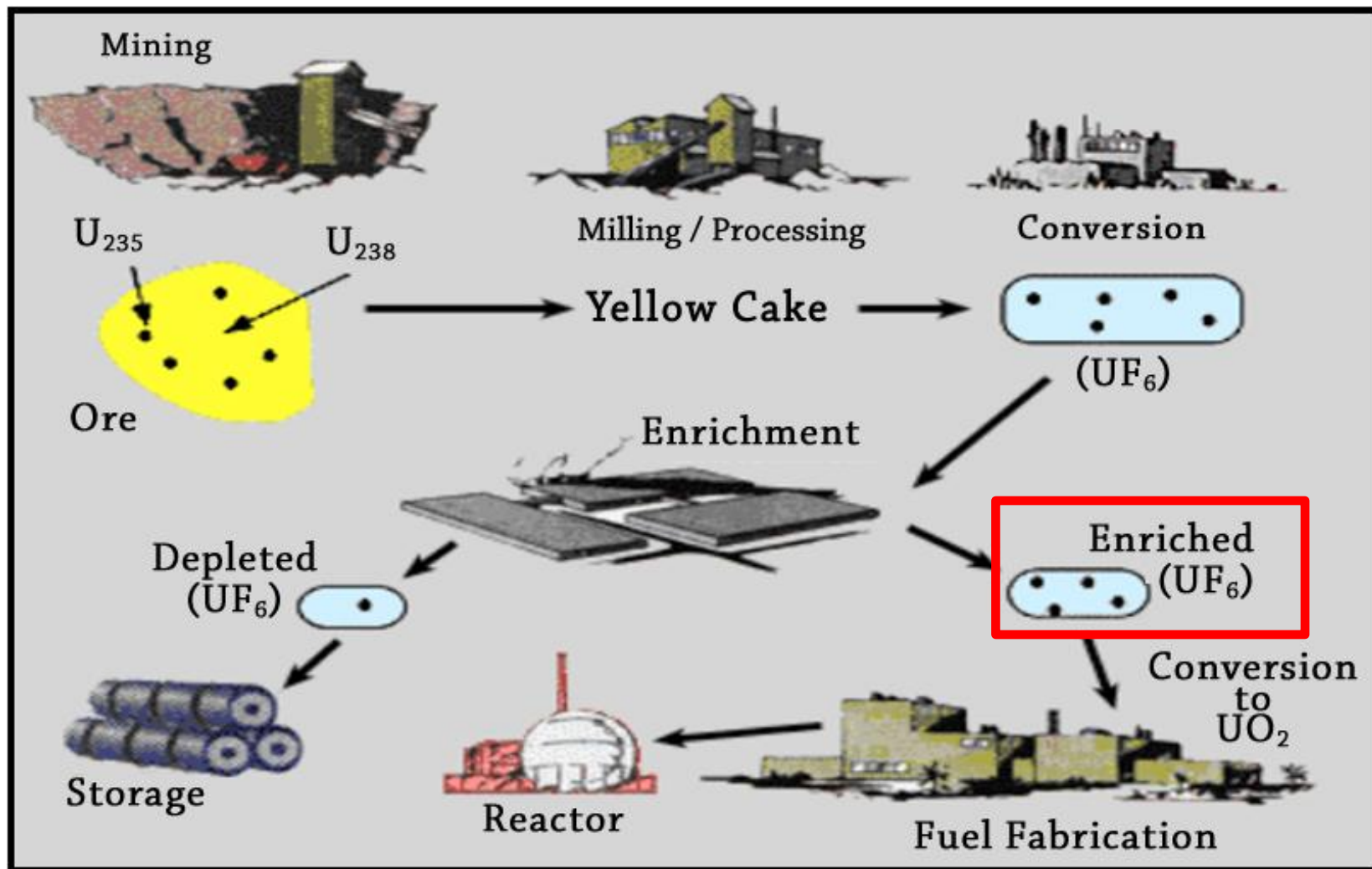
***In Situ Recovery
Production Well***



***Marketable
Uranium
Concentrate
“Yellowcake”
Product***



R&D Effort Supporting New Domestic Enrichment Capabilities - NNSA





Current Fuel Cycle R&D Portfolio:

Near Term Needs

Front End

Back End ←

Long Term Needs

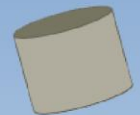
Front End

Back End



Interim Storage

- Evaluating extended time frames
- Transportation after storage



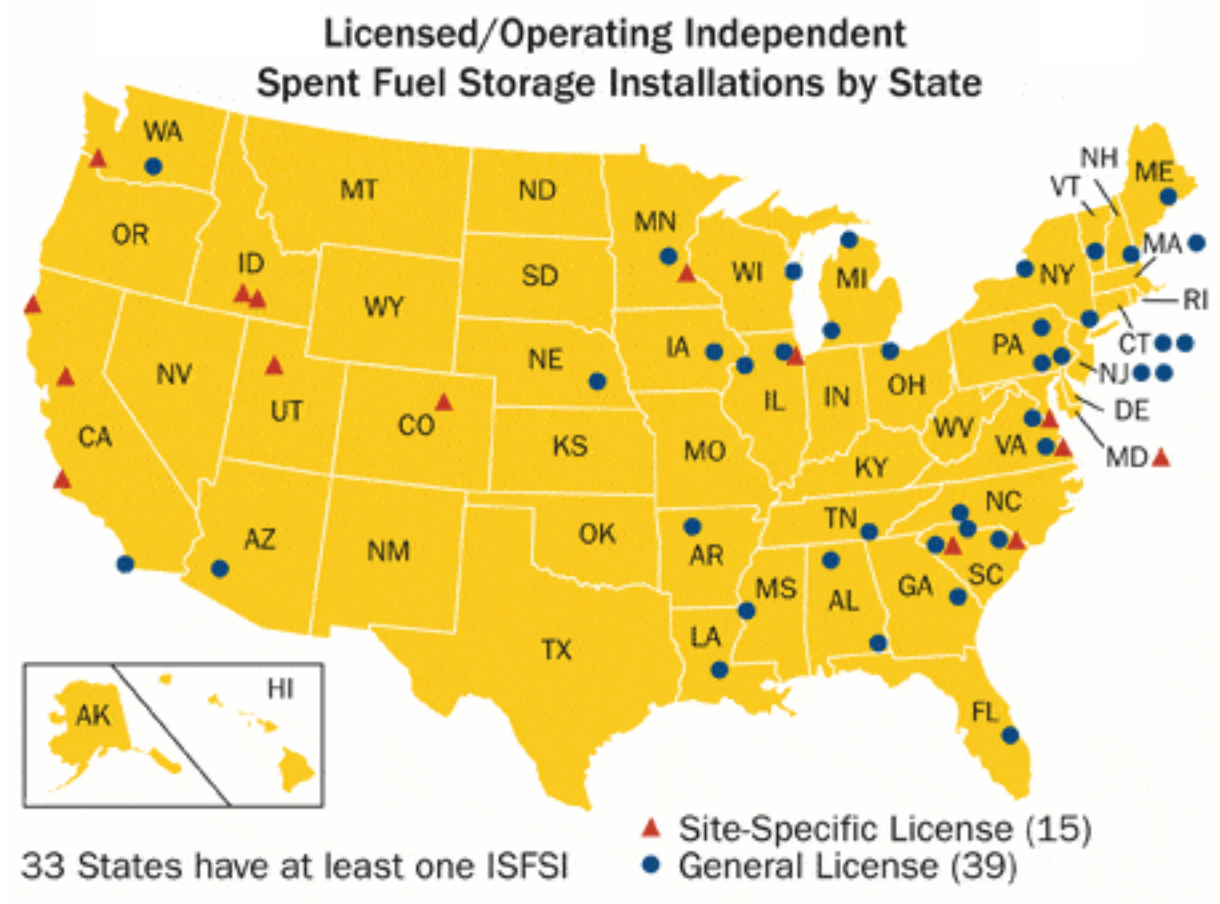
Disposal

- Alternative geologies
- Alternative waste forms



Current Storage of LWR Fuel

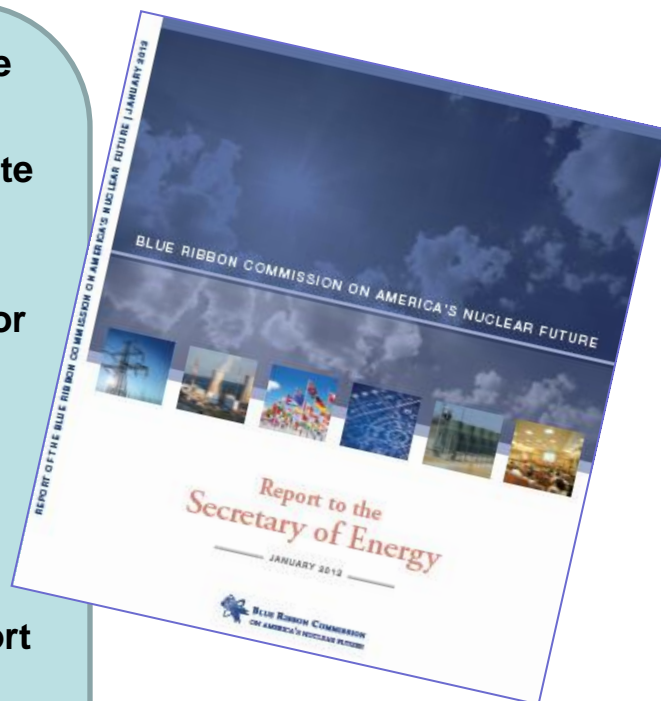
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Blue Ribbon Commission Recommendations

1. A new, consent-based approach to siting future nuclear waste management facilities.
2. A new organization dedicated solely to implementing the waste management program and empowered with the authority and resources to succeed.
3. Access to the funds nuclear utility ratepayers are providing for the purpose of nuclear waste management.
4. Prompt efforts to develop one or more geologic disposal facilities.
5. Prompt efforts to develop one or more consolidated storage facilities.
6. Prompt efforts to prepare for the eventual large-scale transport of spent nuclear fuel and high-level waste to consolidated storage and disposal facilities when such facilities become available.
7. Support for continued U.S. innovation in nuclear energy technology and for workforce development.
8. Active U.S. leadership in international efforts to address safety, waste management, non-proliferation, and security concerns.





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Secretary of Energy Dr. Steven Chu Statement on the BRC Recommendations



The Department recognizes that the BRC Report represents *“a critical step toward finding a sustainable approach to disposing used nuclear fuel and nuclear waste.”*

The Department acknowledges that *“the specifics of a new strategy for managing our nation’s used nuclear fuel will need to be addressed in partnership with Congress.”*

-Administration strategy to Congress within 6 months

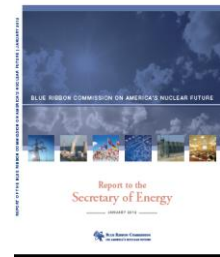
The Department *“will work in parallel to begin implementing the new strategy”* by taking sensible steps toward the implementation of near-term recommendations.



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BRC Assessment of Current DOE-NE UFD Program (Section 7.8 Near-Term Steps)



“Strongly believes that new institutional leadership is critical to getting the nation’s nuclear waste management program on track”

“Recognizes that it could take several years for a new organization to be authorized, funded, staffed, and fully launched”

Confirms the importance for *“DOE to keep the program moving forward through non-site specific activities, including R&D on geological media and work to design improved engineered barriers”*

Recommends the continuation of activities currently conducted under the DOE-NE Used Nuclear Fuel Disposition Campaign

“Identify alternatives”

“R&D on transportation, storage, and disposal options for SNF from existing and future fuel cycles”

“Other non-site specific generic activities, such as support for and coordination with states and regional state government groups on transportation planning”

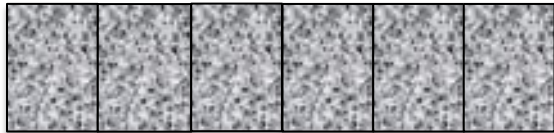


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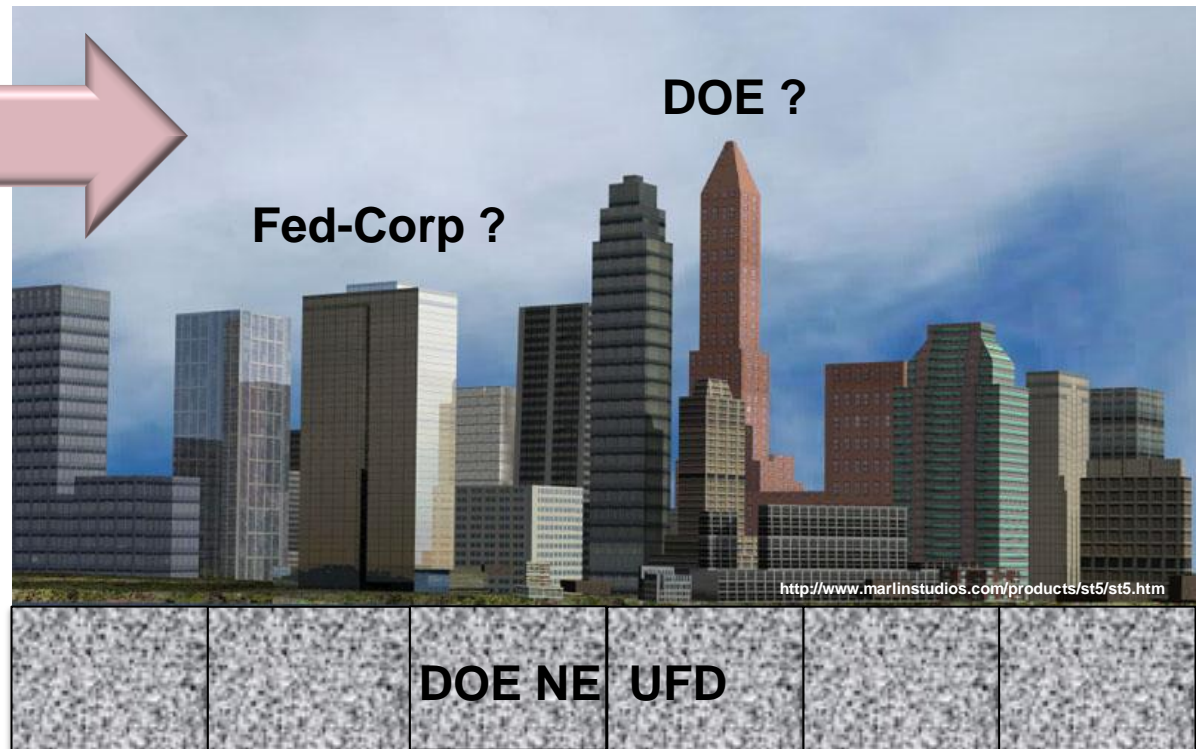
Building the Foundation to Support the Potential New Waste Management Organization

DOE- NE
UFD Campaign



R&D Focus Areas:

- Storage
- Transportation
- Disposal





Storage and Transportation R&D Objectives

- Develop the technical basis for extended storage of used nuclear fuel
- Develop the technical basis for fuel retrievability and transportation after extended storage
- Develop the technical basis for transportation of high-burnup used nuclear fuel





■ Begin laying the ground work for implementing consolidated storage.

- Building on previous DOE work and industry storage licensing efforts, evaluation of design concepts for consolidated storage.
- Develop communication packages for use in interaction with potential host communities, which describe various attributes of a consolidated storage facility.



■ R&D to better understand potential degradation mechanisms in long term dry cask storage including:

- Continue material testing to support modeling and simulation of used fuel aging.
- Complete the identification of data gaps to support license amendments beyond 40 years for dry storage.
- Define facilities needed to conduct the required additional testing of irradiated nuclear fuel. Data with respect to high-burnup fuel is particularly needed.



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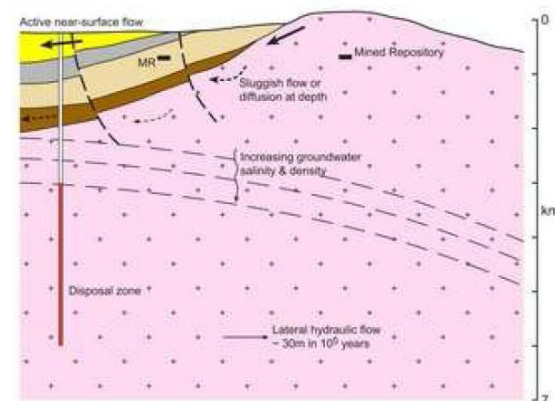
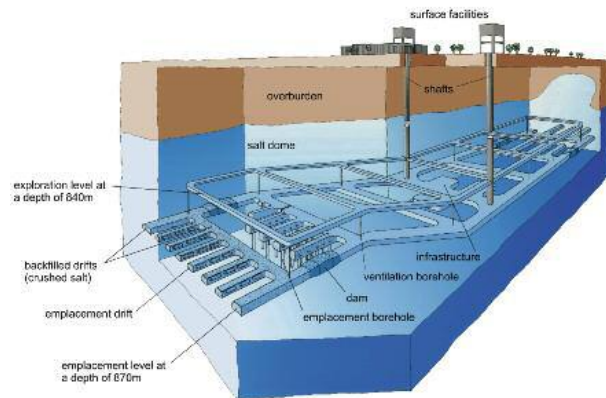
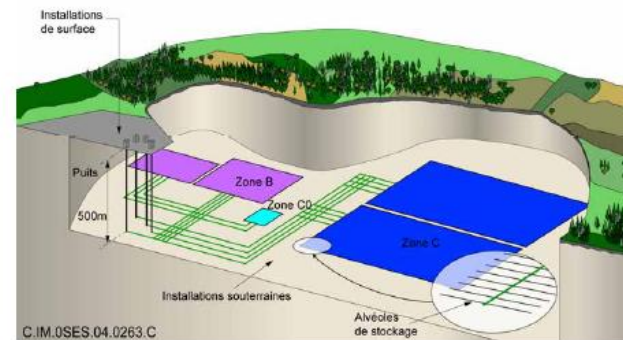
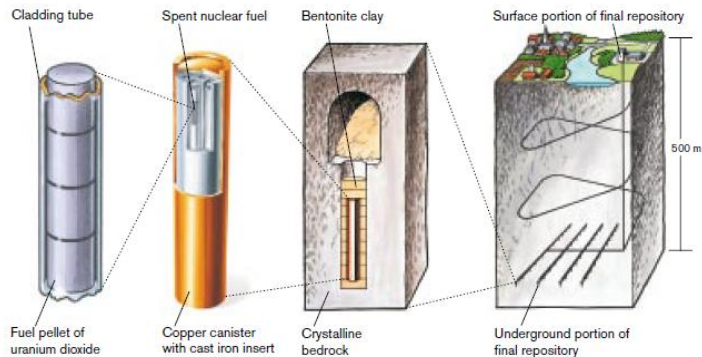
- In conjunction with R&D to support extended storage, data gathered will additionally support the licensing of transportation of casks following extend storage periods.
- Revisit the recommendations of the 2006 National Academy of Sciences report on transportation of spent fuel and high level radioactive waste and prepare a report on plans to address these recommendations. This includes re-engaging the regional transportation groups to understand stakeholder issues.
- Begin finalization of the procedures and regulations for providing technical assistance and funds for training local and tribal officials in areas traversed by spent fuel shipments, in preparation for movement of spent fuel from shutdown reactor sites to consolidated storage.
- Begin conducting evaluations to improve efficiency of transportation by serving decommissioned sites. This will include evaluation of the hardware requirements, timing, and costs.





Disposal R&D is Focusing on Four Basic Disposal Options

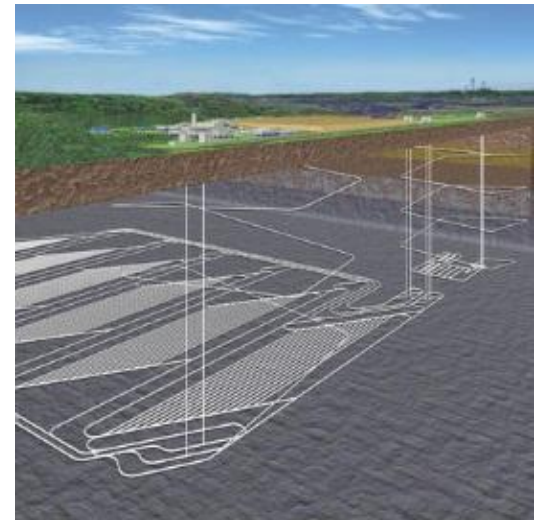
- Three mined repository options (granitic rocks, clay/shale, and salt)
- One geologic disposal alternative: deep boreholes in crystalline rocks





Disposal R&D Objectives

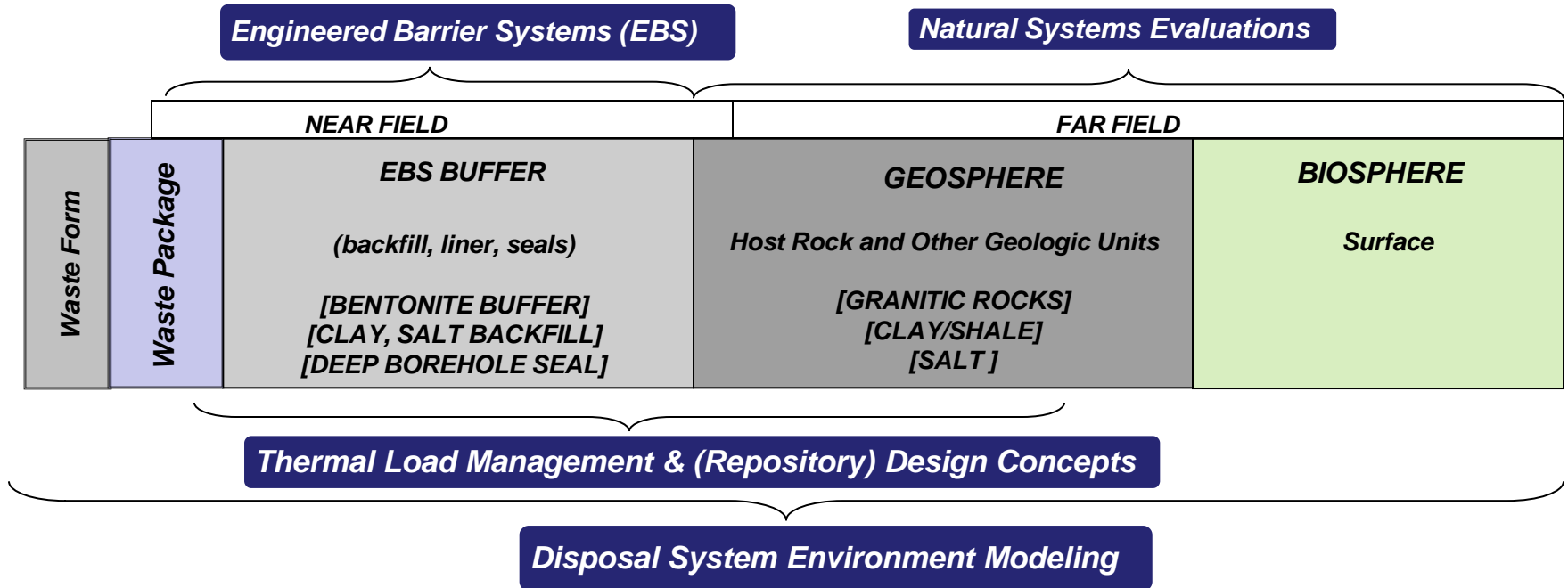
- **Provide a sound technical basis for the assertion that the U.S. has multiple viable disposal options**
- **Increase confidence in the robustness of generic disposal concepts to reduce the impact of site-specific options**
- **Evaluate the BRC recommendation for developing a near term plan for taking the borehole disposal concept to the point of a licensed demonstration**





Activities in Disposal

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SUPPORT, ANALYSIS & EXPERIMENTAL ACTIVITIES

*Engineered Materials Performance
Features, Events & Processes
Low Level Waste Disposition Issues
Inventory Projections*

*(corrosion, degradation studies)
(how R&D is organized and prioritized)
(part of total nuclear waste consideration)
(LLW/HLW, used fuel, open → closed fuel cycles)*



Activities in Disposal – International Collaboration

Formal collaborative R&D arrangements with three ongoing European programs

Major current or soon-to-be started experiments

HE-E Heater Test:

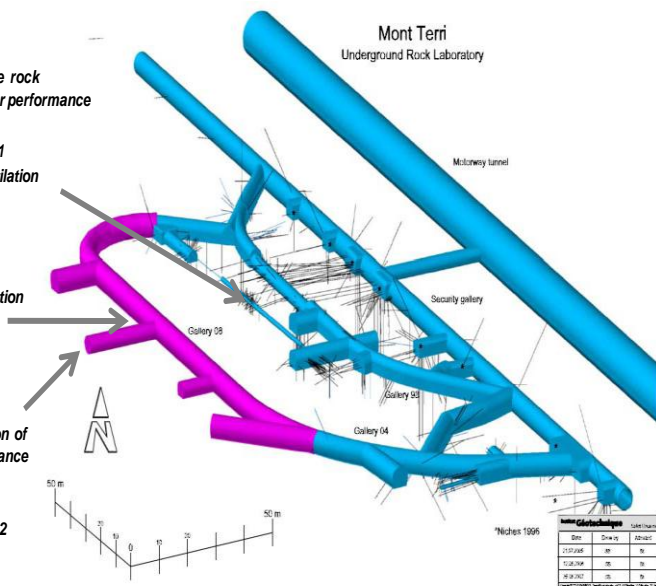
- Focus on THM effects, bentonite rock interaction, seal and clay barrier performance
- Micro-tunnel
- Monitoring starts in Spring 2011
- Same location as previous ventilation experiment

MB (Mine-by) Test:

- Focus on HM effects, EDZ evolution
- Full-scale tunnel
- Monitoring phase completed

FE Heater Test:

- Focus on THM effects, validation of various bentonite/clay performance processes
- Full-scale tunnel
- Monitoring starts in Spring 2012



- ❑ **Mont Terri:** International underground research laboratory (URL) in clay in Switzerland

- *Joining the URL will give DOE access to data from all Mont Terri R&D, also the opportunity to conduct new experiments*

- ❑ **Colloid Formation and Migration Project**

- *Colloid research at Grimsel granite URL in Switzerland*

- ❑ **DECOVALEX: (Development of Coupled Models and their Validation against Experiments)**

- *DOE has participated in the past. New phase of project begins Spring 2012.*



Uranium
Resources

- Conventional production
- Innovative approaches



Current Fuel Cycle R&D Portfolio:

Near Term Needs

Front End

Back End

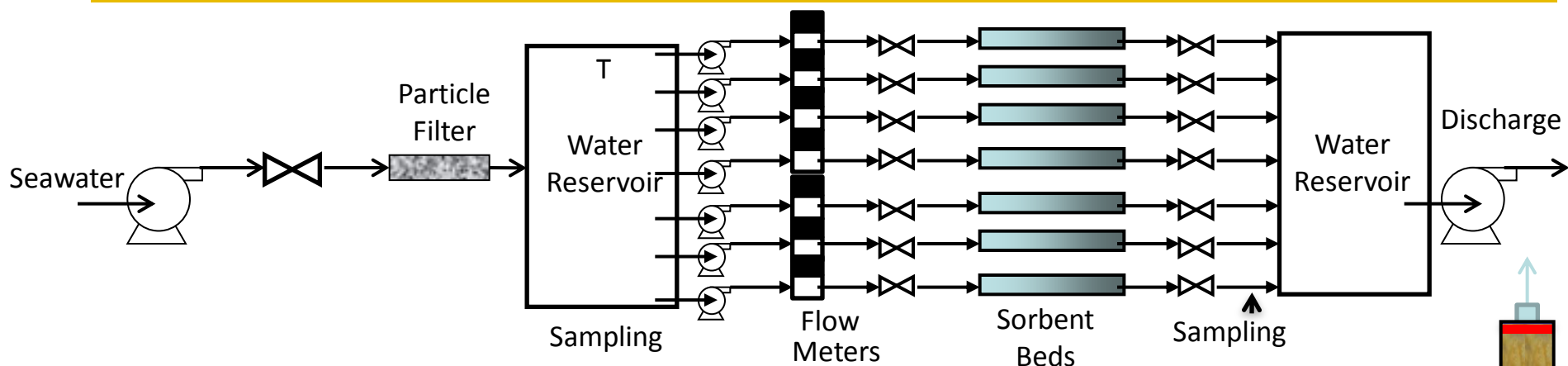
Long Term Needs

Front End

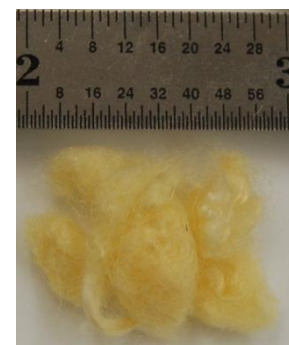
Back End



Uranium Resources – R&D for Recovery of Uranium from Seawater



- ☐ Extracting uranium from currently unattractive but abundant sources, such as seawater, can provide an “endless” source.
- ☐ Investigating the next generation of advanced adsorption technologies that enable an economic recovery of uranium from seawater.
- ☐ Recovering this resource at an economically competitive cost is a technical challenge but this value sets an upper limit in the uranium market price.



Functionalized
fibers

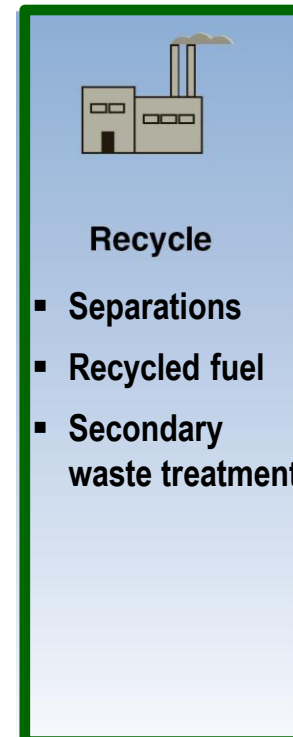
Fixed bed



Current Fuel Cycle R&D Portfolio:

Near Term Needs
Front End
Back End

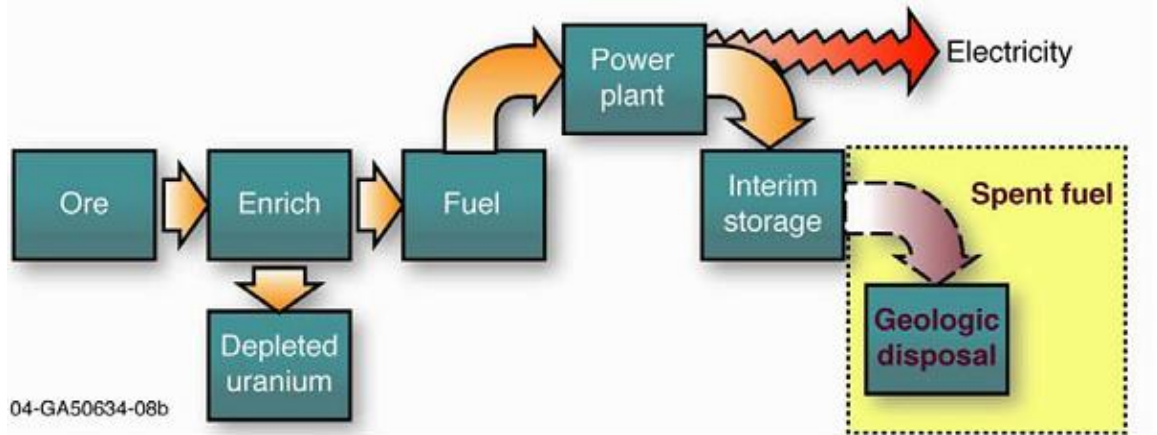
Long Term Needs
Front End
Back End



Evaluating the benefits of moving from an open to a closed or partially closed fuel cycle



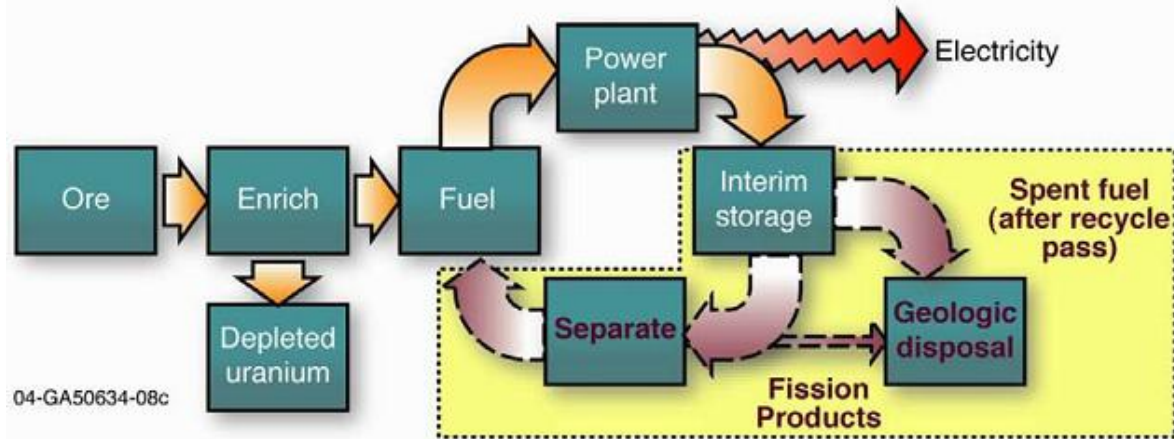
Once-Through Nuclear Systems – Includes Current U.S. Fuel Cycle



- Continuing storage of a growing spent fuel inventory
- Interim storage and geologic disposal still needs to be implemented
 - What is the impact of alternate disposal system environments?
- Are there “promising” once-through options?



Closed or Partially Closed Nuclear Systems – Include Recycle



■ What are the benefits for recycle systems?

- Does irradiated fuel have “value” that can be recovered by reprocessing?
- Are there operational and/or storage advantages?
- Does HLW offer disposal advantages over SNF?

■ Numerous options, including limited or continuous recycle, different reactors and fuels, use of extended storage, disposal, etc.

- How do we determine what are the “promising” alternatives?



What Are the Challenges for Selecting Options for Further Development?

- Complex problem with many complex technologies
- Numerous fuel cycle options possible
- Numerous studies in the past with no clear consensus
- Long time horizon
- Multiple interests and stakeholders
- Variations in policy directions over time

“To its credit DOE has taken a systematic approach to planning for the complex, scientifically challenging process of identifying and selecting sustainable nuclear fuel cycle options and associated technologies...”

Government Accountability Office



Fuel Cycle Screening R&D Objectives

- **Provide a systematic, objective, and traceable method for evaluating and categorizing nuclear fuel cycles according to their performance potential in meeting FCT program objectives**
- **Enable R&D needs to be identified and prioritized more clearly, which enables better communication of the rationale for R&D funding decisions**
- **Allow the program to more rapidly adapt to future policy changes including any decisions taken based on recommendations by the Blue Ribbon Commission on America's Nuclear Future**
- **Facilitating dialog among a variety of stakeholder groups interested in U.S. energy policy and the future of nuclear energy in the U.S.**



Activities in Fuel Cycle Screening

- **Develop a comprehensive fuel cycle option list**
 - Similar fuel cycles collected in a single option group
- **Metrics development**
 - Calculation of quantifiable objective metrics
- **Develop evaluation and screening approach and tools**
- **Conduct the evaluation and screening**
- **Identification of possible R&D directions**
- **Independent review of process and outcomes**



Advanced Fuel Cycle Technology Development Is Science-Based, Engineering-Driven

- **Focusing on three overarching fuel cycle options:**
 - *Once Through*
 - *Closed or Partially Closed*
- **Defining and considering a broad range of fuel cycle technologies supporting:**
 - *Fuel stabilization, waste management and national security material recovery*
 - *Advanced fuels and enhanced accident tolerance LWR fuels*
 - *Addressing proliferation and terrorism risks*

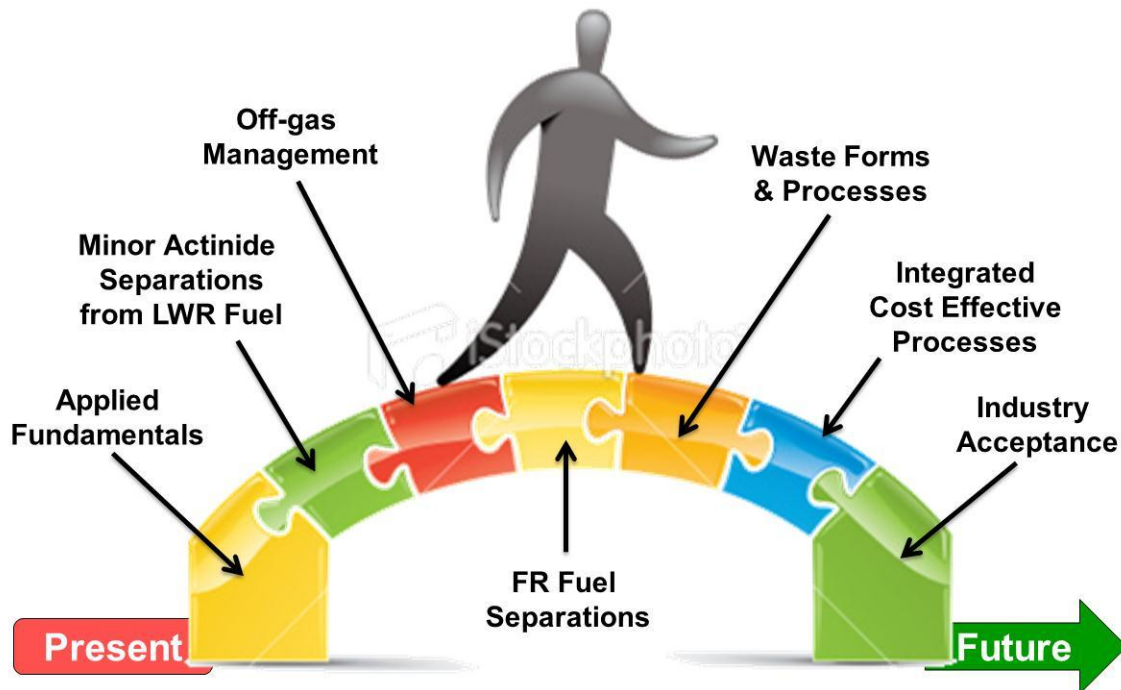


By the middle of the next decade, engineering scale experiments on a new generation of advanced technologies will enable their deployment by the middle of the century



Material Recovery for Fuel Stabilization, Waste Management, and National Security - R&D Objectives

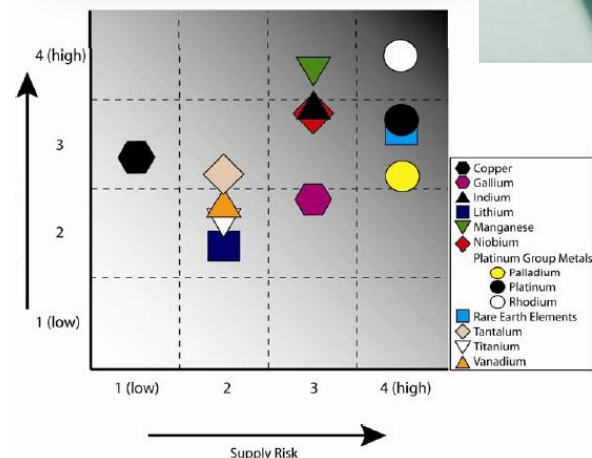
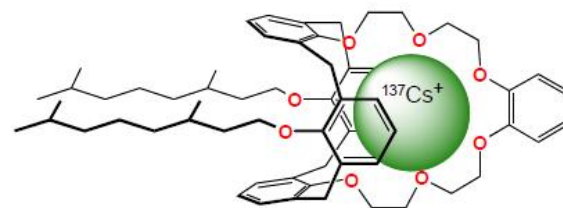
- Develop the next generation of fuel cycle and waste management technologies that enable a sustainable fuel cycle, with minimal processing, waste generation and potential for materials diversion
- Develop economic recovery of national security materials for recycle/ destruction
- Established the foundation of cooperation between EM, NE, NNSA and SC





Activities in Material Recovery for Fuel Stabilization, Waste Management, and National Security

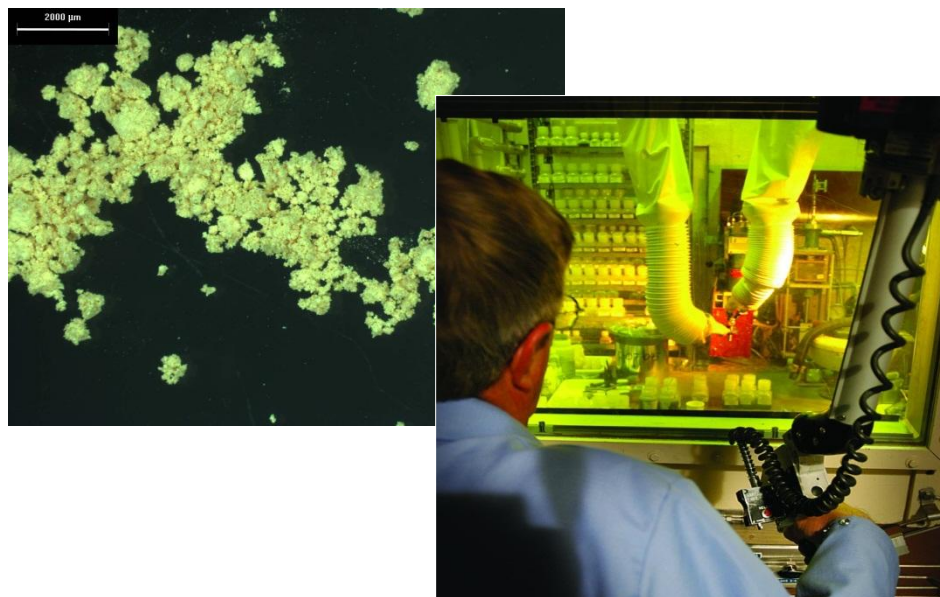
- New modeling and simulation tools based on fundamental science principles
- Technologies for TRU recycle options from LWR fuel
- Economic off-gas capture technologies
- Disposal options with higher-performance waste forms
- Development and demonstration of technologies supporting fast reactor fuel reprocessing
- Separation/purification of rare earth elements in support of critical materials strategy



Advanced Fuels and Enhanced Accident Tolerant LWR Fuels

- R&D Objectives

- Develop “next generation LWR fuels and cladding” whose characteristics include improved operating margin, accident tolerance and high burnup
- Develop “transmutation metal fuels” with a high degree of tolerance to accident conditions and that represent advancements in resource utilization and reduced waste





Activities in Advanced Fuels and Enhanced Accident Tolerant LWR Fuels

■ Innovative LWR Fuels and Cladding

- Better safety performance (e.g. during normal operation, design basis accidents and beyond design basis accidents)
- Reliability and fuel configurations similar to current fleet
- Acceptable economics
- Favorable neutronics and licensing characteristics
- Workshop scheduled for March 29th in Salt Lake City



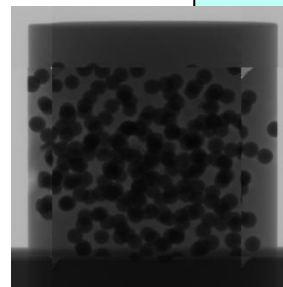
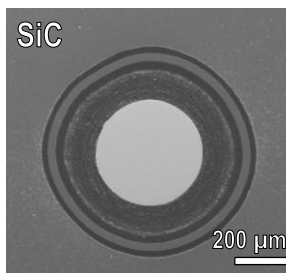
Once-Through

Modified Open

Continuous Recycle

■ Advanced fuels in support of closed or partially closed fuel cycles

■ Advanced fuel fabrication methods with a low degree of losses



Advanced Fuels

High-burnup LWR fuels

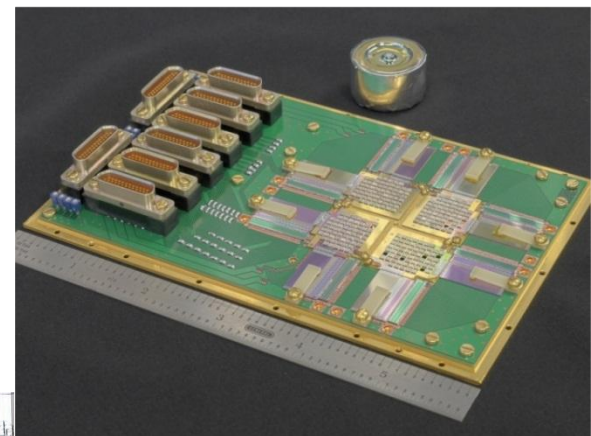
- Deep-burn fuels or targets after limited used fuel treatment
- High-burnup fuels in new types of reactors

- Fuels and targets for continuous recycling of TRU in reactors (possibly in fast reactors)

Addressing Proliferation and Terrorism Risks

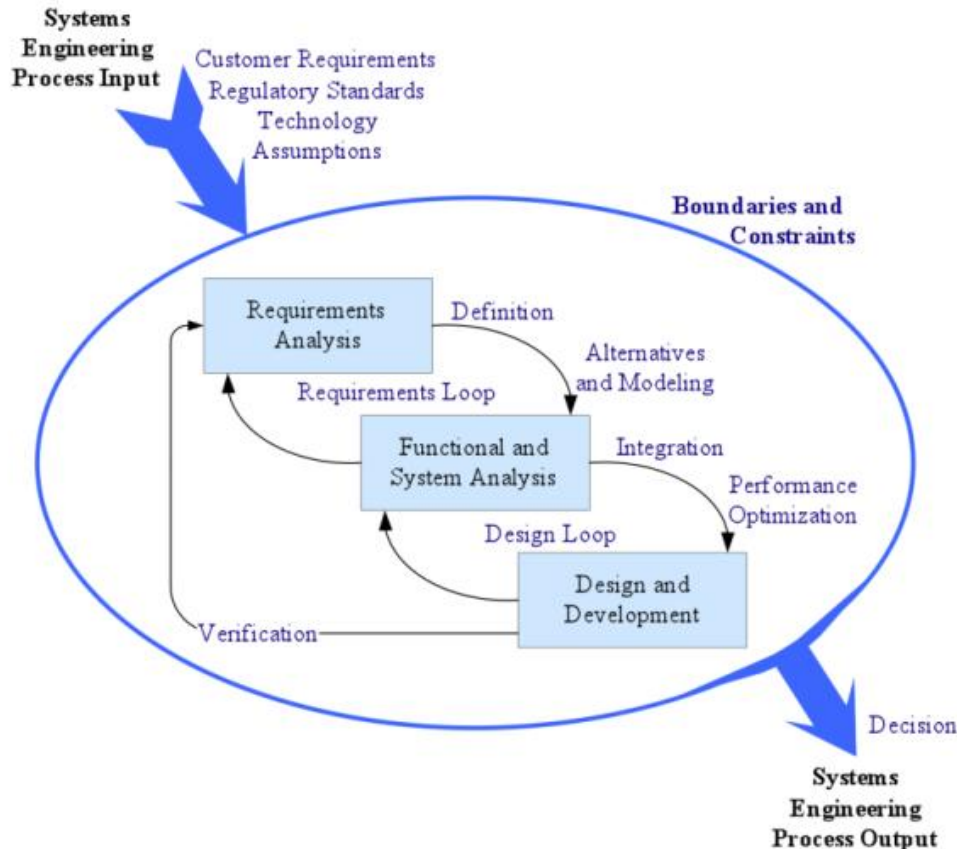
- R&D Objectives

- **Apply Safeguards and Security by Design by considering proliferation and terrorism risks from the very earliest stages to maximize effectiveness and efficiency and minimize S&S costs**
- **Develop instruments capable of real-time measurement of group transuranics in advanced fuel cycle systems**
- **Develop proliferation risk analyses applied to advanced fuel cycles and spent fuel storage**

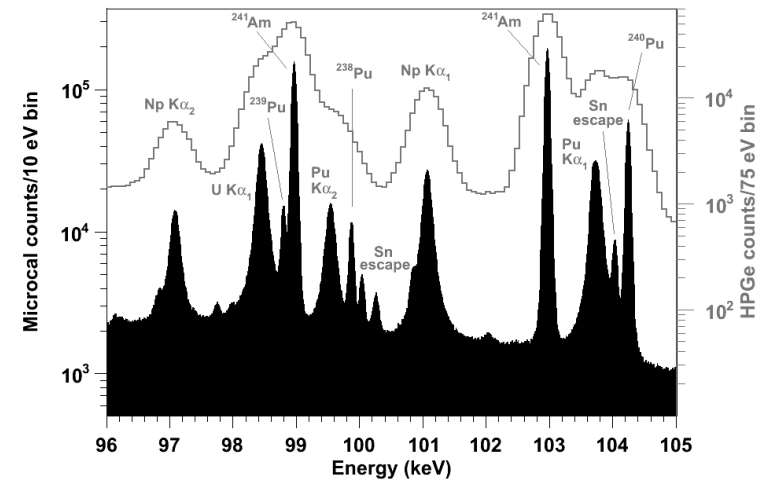




Activities Addressing Proliferation and Terrorism Risks



- Develop national security material management systems for advanced nuclear systems
- Improve national security material management systems at large fuel cycle facilities



- Develop innovative process and facility design features that: (1) enable intrinsic safeguards and security and (2) facilitate extrinsic safeguards and security for nuclear facilities



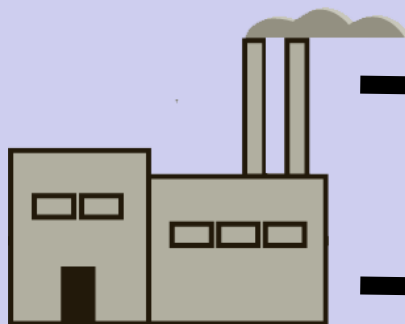
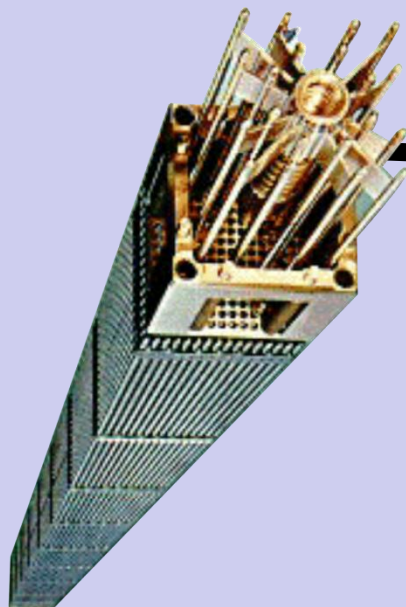
Where Do We Want to Be?

**Near term – Improve management of SNF
Complete our open fuel cycle**



Long term – Focus on sustainable fuel cycle

Used Fuel

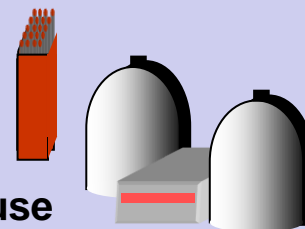


Recycle

**Economically
Safely
Securely**

Product

- Ease of reuse
- Retain high U/Pu ratio



Waste

- Reduce secondary streams
- Ease of Management
 - Storage
 - Transportation
 - Disposal





Concluding Remarks

- **Nuclear energy must play an important role in any future national energy portfolio.**
- **Fuel Cycle Technologies is developing used nuclear fuel waste management strategies and sustainable fuel cycles to help advance nuclear power as a resource necessary for ensuring the nation's energy security.**
- **Where we want to be:**
 - Near term: (1) improve management of SNF, (2) complete our open fuel cycle
 - Long term: focus on sustainable fuel cycles
- **The current fuel cycle R&D portfolio includes:**
 - Mining and new domestic enrichment capability
 - Used nuclear fuel disposition activities in storage, transportation, and disposal
 - Uranium resources
 - Screening fuel cycle options
 - Material recovery for fuel stabilization, waste management, and national security
 - Advanced fuels and enhanced accident tolerant LWR fuels
 - Addressing proliferation and terrorism risks
- **ANNOUNCEMENT – Nanonuclear Workshop**



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NANONUCLEAR

2012

- **Workshop June 6-8, 2012, in Gaithersburg, Maryland**
- **Initial workshop by invitation only, follow-on open workshops are planned**
- **Objectives:**
 - Shielding materials more effective and significantly lighter and thinner.
 - Materials immune to the effects of radiation.
 - Fuels that can last the life of the reactor and robust enough to withstand beyond design basis accidents.
 - Instruments that measure performance in situ, real-time.
 - Selectively remove fission products from waste streams.

